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PROGRESS IN MANUFACTURING PRACTICE.

Paper presented to the Institution, Birmingham Section, 18th September, 1929, by J. H. Garnett, A.M.I.Mech.E. (Member).

(*Also presented by Mr. Garnett to the Luton, Bedford and District Section, Luton, on the occasion of the Inaugural Meeting, 11th December*, 1929).

THE engineering activities of this country are so many and varied that it is impossible in a paper of reasonable dimensions to consider all the directions in which progress in manufacturing practice is to be observed. This paper is, therefore, confined to a few typical cases. These have been selected, not only for their individual interest, but as being indicative of the lines on which the metal working industries generally are developing.

The need for complete technical reorganisation in many of our factories is a matter that has been given considerable prominence during recent years, and a strong case can be put forward showing that many of our efforts at production, whether in respect of buildings, equipment or methods are still inadequate and out-of-date. On the other hand, and more particularly since the war, a general

improvement is noticeable in manufacturing practice with the result that the industries concerned are in a position effectively to counter foreign competitive efforts.

In considering British industry it should be remembered that we are the oldest manufacturing country in existence, at all events so far as engineering is concerned. During the course of time customs have developed that have become traditional and are not readily disposed of. One might also remark on the slow and irksome course matters which effect large interests usually pursue. Bearing this in mind the position is by no means as black as it is sometimes painted. Speaking generally the author is of opinion that given an equal set of conditions, British manufacturers can give as good an account of themselves as manufacturers in any other country, and are not wanting in enterprise and originality.

No greater tribute could be paid to British industry than is to be found in the recent decision of United States manufacturers to take up the production of the Austin seven h.p. car. That a vehicle of this description should have attracted the attention of a country with such manufacturing facilities at her disposal is a credit to British ideas of design generally and to Sir Herbert Austin in particular. Again the magneto industry, which was literally forced upon us under exceptionally difficult circumstances, has been developed and on the score of both price and quality the British product commands a ready market the world over. Another noteworthy achievement, rendered possible as a result of the grouping of our railways, is concerned with the application of line methods to the construction and repair of locomotives, carriages and wagons. This particular system has been adopted by the L.M.S. Railway Company, at both Crewe, Derby and Newton Heath, and is operated on a scale commensurate with the most advanced motor-car manufacturing practice. The reduction in production costs that have been effected as a consequence has been phenomenal. Even in 1928, when the system had not long been in operation, the time taken at Crewe completely to overhaul a locomotive had been reduced from forty days to twelve to eight days, depending on the size of the engine. There had also been a slight reduction in the number of skilled operators employed, despite the greatly increased production. It may be noted that not only have line methods been applied to the dismantling and re-building of the locomotives, but also to tenders, boilers and component parts.

There are numerous other directions in which progress has occurred and in commenting upon these the predominant note is reduced cost of manufacture. This may emerge not merely as a result of some improved method of machining, but through the adoption of new materials, a different form of construction, as the outcome of standardisation or improved organisation.

In the matter of organisation, the L.M.S. Railway Company's

effort which has just been mentioned constitutes the most effective example within the author's knowledge. At the same time it is worthy of note that in shipbuilding, bridge building and heavy structural work the methods of working plates and bars have been improved by the adoption of somewhat similar principles. At some shipyards hulls are being launched in about one-third the time that was taken not more than two or three years ago, mainly as a result of improved organisation and the adoption of better methods of fabrication.

With regard to materials it would appear that industry is on the eve of interesting developments in connection with plastic mouldings. The synthetic bonded materials used for these mouldings have recently been improved and are now obtainable in qualities having a much higher impact strength than hitherto. This opens out an entirely new field for the mouldings and they are already being made in sizes and adopted for purposes that were not considered practicable a short time ago.

One interesting example is to be found in the production of explosion pots for oil circuit breakers. These are a development of British Thomson-Houston Co., Ltd., Rugby. They are made from synthetic bonded paper with a wall thickness of over one inch and weighing up to twenty-two pounds. A point about the mouldings is that in addition to giving adequate mechanical strength and perfect electrical insulation, they entirely eliminate the machining and assembly of a number of separate pieces.

Another example of development in the material field is nitralloy steel. This is a steel in which, by the nitrogen process, a high degree of hardness is obtained at a low temperature. Its main applications are to the wearing parts of machines, motor cars, and so forth, but it is also being used with very satisfactory results to facilitate production. Burnishing broaches of nitralloy steel have been giving effective service after five weeks continuous use, whereas ordinary steel broaches have given out in under two days. Die blocks made of nitralloy steel have made over 9,000 stampings with the first impressions as compared with an average of 4,000 from carbon steel die blocks. When the cost of die sinking, the gradual failure of the die impressions and interruption of the machines for tool changing are taken into consideration, developments of this nature assume an aspect of real importance.

The question of standardisation in relation to cost reduction constitutes a subject in itself and upon which only passing reference will be made. Amongst Diesel engine builders the practice has grown of standardising a cylinder unit and using these units in multiple for engines of varying ranges of horse power. Thus an engine of 25-h.p. will have one cylinder, an engine of 50-h.p. two cylinders, and so on. This very materially reduces the number of different components required to build a range of engines, with a

result that the parts which have to be produced are required in larger quantities and can be handled on much more intensive lines than would be possible under other circumstances. Development on similar lines is noticeable in the motor industry. Several manufacturers are building four and six-cylinder engines in which all components other than cylinder blocks, crank and cam shafts are common to both.

The Cutlery Trade.

In the synopsis, mention is made of the passing of the cottage industry. This is a question that emerges in connection with the comments which are to be made on the subject of cutlery and locks. In each of these trades hand methods have survived until quite recently and to some extent are practised to-day.

The cottage industry is a relic of olden times when goods were manufactured by the craftsman in his own cottage. The textile and boot industries used to be conducted on these lines, but except as a novelty the practice died some years ago and was replaced by mechanical production. In the cutlery and lock trades, the last two years has seen a substantial change and production is now conducted on a mechanical basis and by methods which evince striking originality, with the result that the industries concerned are being placed in a supreme position in the world's markets.

The home of cutlery is, of course, Sheffield, and to its citizens cutlery means as much, if not more, than motor cars to Coventry or brass to Birmingham. In short, the foundations of Sheffield industry are built on cutlery. It is small wonder then that the city should take pride in its new development and at having redeemed one of our very oldest industries.

To describe the production of cutlery it may be said there are three general methods of making a knife blade (1) stamping, (2) rolling (3) goffing.

The third method represents Sheffield's interpretation of mechanical production and has the distinction of retaining, or even improving on, the most valuable characteristic of the old hand-forged blade. Steel, and particularly stainless steel, which is now commonly used for cutlery, is improved by hammering. By the goffing method this is ensured. Furthermore, the hammering is performed in a uniform manner.

The stamping method is used for cheap cutlery and is novel, in that knives produced by this method can be sold at highly competitive prices. In the matter of quality, however, the knives are inferior to the goffed article.

The rolling method is more or less standard practice in America. It provides for quick production, but does not appear to give quite the same quality blank as the goffed blade. It may here be noted that attempts in America to produce cutlery on a mass production

basis have been responsible for considerable financial losses. On the other hand, Sheffield is to-day turning out more cutlery than at any other period in history and possesses the largest and most efficient goffing shops in the world.

(*A series of slides were used to show various types of cutlery, including knives produced by stamping, goffing and rolling, and hand-forged methods. Also of forks and carving knives. Commenting upon these, it was pointed out that to produce a rolled blade there were four operations, as compared to five for the goffed blade, the material used in both cases was approximately the same and consisted of a flatted section steel bar*).

The hammer used for goffing operations is of the bow spring type, the tup which weighs one and a half cwts being reciprocated at 350 r.p.m. Control is by a foot operated friction clutch, and is very sensitive in operation, enabling the operator to secure very fine results.

The machine used for rolled blades was originally developed during the Boer War, when the demand for bayonets was heavy and improved methods of production were imperative. The rolls are eccentric and the blade is rolled down from the bar stock in two passes. A point about rolling is that, unless the stock is uniformly heated, the length of the blade is inclined to vary, cold stock giving shorter blades and vice versa. Also any scale on the stock is rolled into the blade which involves extra grinding and sometimes scrap.

The author admits a great deal more could be said without exhausting the subject of cutlery, but the primary object was to indicate development, and it is in the preparation of the blade up to the point of grinding that the most striking advances had been made. There is, however, a point about the finishing of the knives that is worthy of comment. The cutler is particularly anxious to get down to a proper manufacturing basis, and at least one effort is being made to introduce line methods. This is at the works of Joseph Rodgers and Sons, Ltd., the slide presented being used to show a section of one of the pocket-knife shops where knives are made and assembled by line methods. Table knives and scissors, of which Joseph Rodgers and Sons, Ltd., are the world's largest makers, are similarly produced.

The Lock Trade.

As in the case of cutlery, the production of locks has gradually been converted and placed upon a mechanical basis. In this connection the work done by H. and T. Vaughan, Ltd., Willenhall, is particularly noteworthy. The production of locks has, perhaps, been even more primitive than cutlery. Most of the parts were made from castings which were filed up and worked to shape by hand. To this day many lock keys are malleable iron castings which are

filed up by hand, but the practice of giving them out to craftsmen is dying out. The blanks used to be filed up and delivered to the lock maker for about twenty-eight shillings per gross.

The modern tendency in lock making is to use press methods which have been highly developed at the works just mentioned. Slides are presented of locks in which both the lock and key are entirely pressed steel productions. One example is a six-lever lock which can be assembled in as many as 47,000 combinations, and used to be one of the most expensive types made. Another lock involves a matter of 137 press operations and is sold wholesale at one shilling. A point about the lock is that the locking mechanism is built as a unit and can be embodied in several different types of case.

Gramophone Motor Production.

Gramophone motor production has recently grown to an industry of considerable importance and is developing very rapidly. Although a number of cheap and indifferently-designed motors are being produced in this country, the bulk of the better quality motors are manufactured by three firms. These together are responsible for a yearly output of between one and a half to two million motors. Collaro, Ltd., Culmore Road, Peckham, London, S.E.15, who are the makers of the motor under consideration, producing approximately 10,000 per week. The intention is to produce 500,000 motors during the current year. In 1926 the output was about sixty motors per week, which gives some indication of the size to which the industry has grown in two years.

The motor is a unit that will bear the closest examination and is characteristically British in design and workmanship. One particular feature is the body casting. This is a fine example of moulding and consists of an iron casting in which uprights at each corner are cast integral with the top and bottom plates. In many motors of both British and foreign origin the practice is to use either a die casting or an iron casting with a loose bottom plate. The present design is more robust than either. It cuts out a substantial amount of machine work and is cheap to buy. Actually it is produced by Vono, Ltd., Dudley Port, the castings costing Collaro, Ltd. £26 per ton, a price which works out at 4½d. each. As a casting examined in bulk, the author was very much impressed at the quality, clean and sound appearance. They are delivered in a sand blasted condition, and are finished so far as surfaces are concerned by presenting the faces to a disc grinder. Two youths on a double-ended machine are capable of dealing with the full output at the users' works.

It is understood that a considerable sum of money was spent in equipment for producing the castings and in developing suitable methods, the point that emerges being that to produce on com-

petitive lines one must be prepared to display enterprise and make sacrifices. But, providing the work is properly managed, the reward is adequate.

Heavy Forging Practice.

From cutlery, locks and gramophone motors, to heavy forging practice, represented by the production of hollow and ring forgings is a long step. In a series of slides, hollow and ring forgings and the methods by which they are produced, are shown. The forgings may be anything up to forty tons in weight by forty feet in length and four inches in wall thickness. In some cases the forgings are closed in at one end by forging, but in others they have separate dished ends riveted in.

Generally, the forgings are produced from an ingot which is trepanned through the core and then forged down on a mandrel. In the case of ring forgings, the ring is finally shaped by rolling on the same lines as tyre rolling. These forgings are often as large as fifteen feet in diameter by eighteen feet long. The rough ingots for forgings of the size specified will weigh about 130 tons as cast. After trepanning they are forged down on a 6,000 tons hydraulic press, fitted with the Davy patent automatic single-lever control gear. This makes for rapid action and in conjunction with steam saving gear for economy in operation. With the press accurate, forgings are produced in half the time that is possible with a hammer of equivalent power and for half the steam consumption. An overhead type of manipulating equipment is used for handling work on the press, and this contributes very largely to the speed of production.

Fabricated Steel Construction.

The last example of progress to receive attention is concerned with fabricated steel constructions which are being effectively used in the electrical and heavy engineering industries to replace castings. This is a practice that has made great progress in the United States, but British manufacturers are not lagging behind and in some respects, especially where smaller sizes are concerned, may be considered to have gone a stage further than the Americans.

One British manufacturer who has paid particular attention to the development of fabricated steel is B.T.H. Co., Ltd., Rugby. The examples shown are essentially electrical productions, but the system of production is also being applied to other large work with equally successful results.

In the electrical engineering industry there are certain aims that have to be kept constantly in view. These are (1) reduction in cost of existing types of electrical machinery; (2) improvement in performance and reliability; (3) easier and more rapid manufacture; (4) development or invention of new types of machine

to meet the requirements of new or old industries; (5) new applications of existing types. In furthering these aims fabricated steel construction offers great advantages, and has been standardised by the B.T.H. Co., Ltd. for all their medium and large size A.C. machines.

Stator frames were the first forms of fabricated structure to be developed. Typical examples illustrated were of box and clamped up types. The box type can be built up as a complete unit, then bored and the core assembled in practically the same way as for a cast-iron frame. For a machine with a horizontal shaft, the box type consists mainly of two web plates, which form the vertical sides of the frame. In the case of smaller frames, the web plates are cut out to the exact size and shape from a rectangular steel plate, but on larger machines they are built up of segments cut from a rectangular plate and welded together to give the required size and shape.

The web plates are spaced apart to suit the core length and then thick wrapper plates are welded to the periphery of the web plates. On the inside of the web plates heavy rectangular cross bars are welded at intervals to form stiffening ribs. The keys which transmit the torque from the laminations to the frame are held in slots cut in the cross bars. Substantial feet made from thick rectangular bars are welded to the web plates, and near the top of the frame are welded strong lifting bars. The section of the frame is very similar to that of the previous standard B.T.H. cast-iron frame.

The laminations are held in position axially by substantial steel tooth supports welded to thick steel plate segments having bolts in each segment. These bolts extend across the frame behind the punchings. The box type frame is very suitable for machines that have to be split on the horizontal or vertical diameter.

In the clamped-up type machine the web plates are used to form the clamping flanges for the core, the tooth supports being welded directly to the web plates. The core is built up on one flange and then clamped to the other flange. The assembly is suitably braced and thin sheet steel covers form an outer wrapper plate. A side plate can be removed and damaged laminations can be removed in the same way as with a box type frame. One advantage of the clamped-up type is that no boring of the frame is required.

Many other electrical machines and parts are produced by the same method, including bedplates and alternators.

A further development which is likely to become important is that of fabricated spiders. These can be constructed in various ways depending upon the particular type of motor and the size and speed at which the spider is to operate. In the example used the webs are circular steel plates with a centre boss made from steel bar bored to the required size. Distance pieces are welded between the plates and the rectangular bars welded to the peri-

phery have dovetails subsequently machined in them to take the keys which hold the laminations in position.

Another type of rotor spider for a waterwheel alternator is built up from quarter-inch thick steel plates. The plant and equipment used for working the materials into shape and assembling the different parts largely consists of electric welding and gas cutting jets, supplemented by templet machines for cutting shapes to pattern, bending rolls and similar plate and bar working tools.

In connection with these an interesting note is that as an alternative to rolling when bending circles, which is established practice in America, British practice was to use the vertical boiler plate bending method. This gave much more accurate work and enabled quite small circles to be formed without waste. Another alternative practice was to use large armour-plate frame punching machines for cutting out circular holes in fabricated spiders for induction motors and alternators. American practice for this class of work was to use gas-cutting jets worked by a templet. The punching machine had an indexing mechanism and could produce interchangeable work much more quickly.

The principle advantage of fabricated construction is maximum strength. Maximum strength and soundness are ensured and when compared to castings, the saving in cost is often considerable. Where patterns do not exist the saving is about 40 per cent, and where patterns require alterations, the saving is about 25 per cent. There is also a substantial saving in time by fabricating instead of casting. This is in the region of 40 to 60 per cent, which is important when delivery dates have to be considered. Another point is that fabricated steel is usually about half the weight of cast-iron construction.

Future Lines of Development.

In conclusion it appears desirable to comment on future lines of development, and in considering this the relative positions of Great Britain and her industrial rivals, together with the influence of British quality, are points that spring to mind.

Germany and France are forging ahead very rapidly in the metal working field and competition from these sources must be regarded seriously. Like ourselves, these countries are passing through a stage of development and are naturally experiencing substantially the same difficulties.

The only other really effective competitor is America. This is a land of unusual opportunities, not only for the manufacturer but the individual, and remarkable industrial achievements must be placed to her credit. The fact must not be lost sight of, however, that the foundations of her prosperity were laid during a period when there were vastly more opportunities than there were men to fill them.

The reason why America has made such spectacular advances is due to mass production, and contrary to popular opinion this is not the outcome of any special ability but a condition which emerges as a result of the vast domestic market for which the manufacturer perforce must cater. One should remember in comparing British with American efforts that the population of the United States is about 125,000,000 as against 42,000,000 in this country. Industry, like water, follows the line of least resistance, inasmuch as the manufacturer caters for the market nearest to hand. Therefore, in this respect the American manufacturer is compelled to produce three times as much as the British manufacturer, but actually he accomplishes no more in the matter of distribution relative to population. Still, the fact that he can produce in the ratio of three to one gives the American an important manufacturing advantage which operates to his benefit when considering foreign markets. Methods and machinery can be introduced which the average British manufacturer could not entertain. It is obvious that in order to make an article economically on a mass production basis a minimum demand must exist before special machines can be developed and installed. Otherwise the depreciation, interest costs and so forth on idle time may show a loss over the old methods rather than a saving.

There are many special machine tools which will easily machine a thousand motor-car parts in a day or less. The longer such machines can be operated in a given period the lower the cost per unit. But if there is not the demand for continuous production, each part may be made cheaper by an older method than by installing a new high-production machine, and charging off its cost in non-productive time. Accepting these facts, it is evident that if quantity only is considered, production in America and Great Britain cannot be regarded on an equal basis. The latter is initially under a three to one handicap, and if we are to succeed and hold the markets which have been hitherto regarded as our prerogative a line of quality rather than mass production must be taken.

From the various examples of practice that have been put forward it is possible to prove that given an equal proposition, British manufacturers are fully as capable as American. The production of rolled and stamped knife blades is a case in point. But whilst these provide for an undoubted market the question emerges—do they satisfy the whole demand? The rolled blade is perhaps slightly cheaper and more simple to produce, but in quality it cannot be said to receive the same thorough treatment as the goffed blade. That a stamped blade can be produced and retailed as a finished stainless knife at a cost of sixpence is an achievement which the American would find difficult to equal, but is there not a large public that demands something better?

A point that should not be overlooked is that so long as people

look different, think differently and have different means, just so long will they demand different things. In some, and perhaps the majority of cases, cheapness is the dominant requirement. At the same time there is a demand for better quality just as there is a demand for luxuries. For these reasons the author believes it is in the direction of quality that our salvation lies. Our reputation for quality stands pre-eminent in every sphere of engineering production and, if by improved methods of manufacture and the judicious application of mechanical processes, we can reduce the disparity in price that often exists between two similar articles, one produced by quality and the other by mass methods, we are assured of a substantial share of the world's trade.

That such a course is being taken is demonstrated in the cutlery and in the lock trade. It is also evidenced in the production of gramophone motors. In those branches of mechanical production which do not depend on mass principles, such as fabricated steel construction or the production of heavy hollow and ring forgings, we have in the first case improved on the methods of fabricating, and in the latter case definitely established a lead which no other country as yet has been able to equal.

The author believes the case for rigid mass production has not yet been definitely established. There is latterly a tendency for the American manufacturer to lean towards more elastic methods of production, to permit of his keeping pace with the rapidity of technical progress and changes of fashion, and the next few years may see some interesting developments, in fact, the more one examines the situation the more one is inclined towards the British line of development.

The author submits the proposition that the tendency of technical progress is to make things give better and more lasting service, and the successful development of British mechanical production will depend on the recognition of the truth of this proposition. Trade is not a one-sided affair. It must be mutually beneficial and conducted on terms that will enable one section of trade, or one country to discharge its obligations to the other.

Discussion.

Mr. W. G. Groocock, who presided, said that Mr. Garnett in his opening remarks had thrown out a challenge to production engineers. He had told them that whilst much had been done in production in this country since the war, there was still a great deal left to do. The question arose, just who was to start the process? Some people believed that it should be the directors. Perhaps it was just possible for the directors to begin it, but on the other hand there was no doubt that production engineers were being relied on more and more to put our trade on a better basis. It was up to them to prove that they could do quite as well as production engin-

eers in America. Mr. Garnett had pointed out that the larger production in America was not due to any special abilities, but to their larger home market and the larger quantities they had to deal with. That might be so to some extent, but it was also probably due to one other factor, namely, the desire of people over there to earn higher wages and to increase their output so that they could earn higher wages. Looking at workers in America one was at once struck by their vitality. There was a continuity of production there and American operatives seemed to work more steadily than operatives in England. That question of continuity of work was probably due largely to the desire of the worker himself.

MR. J. A. HANNAY congratulated Mr. Garnett on the large variety of information that he had put before them. During their last two sessions in the Birmingham Section they had had many successful meetings, but Mr. Garnett had taken them out of the ordinary run of topics and given them something altogether different. Mr. Garnett had wonderful opportunities of seeing what was taking place in British manufacture, principally in engineering works, since the war. It was good to hear that Sheffield was holding its trade and they all hoped that it would continue to do so, but he felt that Sheffield had not got down to the proper manufacture of cutlery yet. Look at the knife made to sell at sixpence. If one were to put some piece similar to that in the machine shop one would not allow anything like sixpence for it. Though he had not had much to do with cutlery he felt that very much better could be done. If the Americans were behind us in this, well, they must be very bad. Mr. Garnett, however, had shown them something in locks where there had been improvement, and when one considered what could be sold in that line at a shilling, compared with the knife at sixpence, there was no comparison. To get six levers, and such a multiplicity of combinations, and to get everything to work so sweetly, was a very good job. The key, also, was a fine thing, and he would like to give more attention to the making of that key. He would commend to their attention the coining process shown. That was one of the lines they had got to take up in a lot of their manufactures. Stampers could do a good deal, but with coining one could get absolutely down, one could get a finish which the stampers could not get, though they said they could. As to gramophone motors, they ought to be able to do something better. The cost is wonderful, but at the same time, when electricity is so handy, they ought to have little electric motors that could do the work far cheaper. He would like to hear what the Chairman had to say about that. Given quantities of ten thousand per week, something worth while should be done. The heavy forgings were also wonderful. Nothing had pleased him more than to see how such big stuff could be handled. Years ago he had seen small things such as loco boilers, etc., being made, but to see these very

big ones was a really wonderful performance. It was surprising to find how simply these big jobs were done—just a tap-tap-tap. He could specially commend the fabrications at the B.T.H. company that Mr. Garnett had spoken of. With several others who were present that evening he had had the privilege of going through the B.T.H. works. They were busy making castings. Some of the mould pits were quite the size and very nearly the depth of their meeting room. In making these by old methods, after getting the castings into certain machines, there was always the fear that they might be scrapped. To-day they could be fabricated without any fear at all of scrap. It was wonderful, and they, as engineers, had got to take advantage of it. He had sighed with relief, after he saw those huge jobs being made, to think that they were free from either casting blowholes or other defects. He would not venture to say anything about the American worker as compared with ours, except that somehow or other the American seemed to have got some go in him that was lacking on this side. He was not a better man—it might definitely be said that he was not as good, but he had that bit of extra go that the Britisher lacked.

Mr. Garnett, replying to Mr. Hannay, noted that he seemed rather disappointed about cutlery. It should be pointed out that Woolworth's probably work at about 100 per cent. profit, and the knife at sixpence was probably made at threepence. He agreed, however, that Sheffield had not yet got down to it. The examples shown were by no means universal in Sheffield. The whole of the development had been done in two years. Two years ago it was nearly all hand-forging. He had had a chat with Mr. Palmer, Managing Director of Joseph Rodgers, who had put up a plea that they were particularly anxious to marry the production engineer and the cutlery trade. There were still many industries in this country which were using methods hundreds of years old, such as the hollow-ware, brass-bedstead, and other industries. Frankly, he wanted to bring some of these into the limelight. It was therefore right to mention that the cutlery trade wished the production engineer to take an interest in its propositions. The progress the trade had made in two years was not so bad, and they would get down to something better. The American blade did not strike him as being at all comparable with the English blade. You got the scale rolled in and any slight variation of heat in the stock resulted in blades coming short and long. One thing about the English blade was that you did get a real job. In connection with locks, H. and T. Vaughan were probably about as go-ahead as anybody in the country. There again, the methods they adopted were by no means universal. In fact, H. and T. Vaughan had still got an old hand-working shop, though that would probably disappear very shortly. As to gramophone motors, he thought development was at an interesting stage, where they would entirely scrap

a lot of hand work. It seemed to him that they were just on the eve of wanting something bigger. Possibly, twice the output would cheapen the price of the motor considerably. He was glad to note that Mr. Hannay's remarks about fabricated steel were favourable. From what he had himself learnt of American practice, he thought they were definitely showing America one or two things on fabricated steel.

THE CHAIRMAN, referring to gramophone motors, said it might be quite easy to make gramophone motors electrically driven. At a rate of ten thousand per week they could be made at a lower figure than had been mentioned, but he would suggest that there was another reason why this had not been done in this country. To-day only about 25 per cent. of our houses were electrified, and most of the gramophones went into houses that were not electrified. He thought that was the answer.

MR. R. H. YOUNGASH felt that the Birmingham Section had every reason to be proud of Mr. Garnett's lecture, particularly as he was one of their own members and a member of their Committee. He did not want to offer any comments on the various processes that had been discussed or shown. The explanations given had made the whole thing quite obvious. He would just like to raise one point. Where on earth did they get that terrible word "fabricating"? One could talk about fabricating whisky, but not machinery. Mr. Garnett should endeavour to see that they had a proper term applied to the building of steel stampings.

THE CHAIRMAN said that there was a curious feature in connection with some of the slides that Mr. Garnett had shown them. The rolls for rolling knives, like most of the things in that line, had been developed for war purposes. The abolition of war would mean the abolition of one very strong incentive for improvement in certain production methods, but they could afford to do without such an incentive.

MR. HARMER remarked that Mr. Garnett had only touched the fringe of conditions in the cutlery trade. Production engineers would scarcely credit the conditions that exist in many of the Sheffield workshops to-day. Having described what he had seen on a visit to Sheffield, he said that it could hardly be called progress when these things were still going on.

MR. GARNETT replied that what Mr. Harmer had said was quite true. It was a work of art in some shops to make up the wages each week-end, owing to the numerous rates of pay and processes. One man he had asked about that had replied that he would rather not go into it. As to grinding, he had seen the old sandstones, and it was a difficult matter, with such things as the hanging of the wheel, to get the man to see daylight. But the old conditions were dying out. All the forging examples he had shown were from the shop of G. W. Thornton, who paid his men a wage and had definitely

disposed of all the humbug about piece prices and so on. His shop had only been in operation since the war and he had now the largest goffing shop in the world, and was sending knives into America, Germany, and other European countries in very large quantities. As to the term " fabricated " he could only tell Mr. Youngash that it was the name given to steel by the B.T.H. He would call it welded steel.

MR. D. WILKINSON, who said that he had enjoyed the paper tremendously, pointed out that the reason the term " fabricated " had been applied to steel was the strong objection to welding. If the B.T.H. were to sell their products as " welded " it would cause a lot of suspicion. It sounded well to call the bodies " fabricated." While they were considering progress in manufacture, let them not forget that questions of fresh air, health and cleanliness were looming more and more in the minds of production engineers, and that without due regard to such questions they could never get the best production. Referring to what Mr. Hannay had said about knives, he ventured to suggest that it was a good job. They were stainless blades, and it must be remembered that chromium was still a very expensive metal to obtain. Though there were huge quantities of it in the various metals it cost a lot to extract it.

MR. H. C. ARMITAGE proposed a vote of thanks to Mr. Garnett. Mr. Garnett, he said, had referred to reduction in cost as being one of the principle items of manufacturing progress, and suggested more or less that this reduction was due to new methods or the adoption of new machinery. In nine cases out of ten reduction of cost could be obtained without new machinery. Without spending more money on machinery, costs could be reduced by improving organisation. That, to his mind, was the root of all cost reduction. To produce nearly all the jobs that Mr. Garnett had shown them during his lecture in less time and at less cost, with the exception of the very heavy stuff, was more a matter of organisation than of machinery. They had not seen anything very new in the way of machinery except in the fabricated stuff, from which it almost looked as if electrical works were now more like shipyards. Nearly all the improvements were in the line of organisation and simplification and the reduction of actual cost through improved design. That was shown in the case of the lock described by Mr. Garnett. He agreed with Mr. Hannay in his criticism of the knife industry. When one compared the lock, with its 137 operations, to sell at one shilling with the knife, with its seven or eight operations, the contrast was astonishing. It would be interesting to know the cost of material in the knife compared with the labour cost. He was very surprised to learn that the fabricated stuff was cheaper than castings. If one were to commence production in big quantities and attempt to use fabricated steel, either as against stamping or casting, and machine it, fabricated steel was likely, in his opinion,

to be very much more expensive than either the casting or the stamping. Welding was very expensive under present-day conditions. With regard to nitralloy, he had not had any experience, but understood that it was something like Widia or Carboly. They would have to get a totally new technique for working it, and in that direction there was still a lot of progress to be made. He proposed the vote of thanks to Mr. Garnett with very great pleasure.

MR. GARNETT, in acknowledging the vote of thanks, agreed with Mr. Armitage that the main question was one of improved organisation. An example of that was to be seen at the L.M.S. railway works at Crewe and Derby. Crewe, as he had said, had reduced the price for overhauling locomotives from forty days to twelve to eight days by nothing but improved organisation. They had many old machines still in use. It came back to what the Chairman had said about the attitude in America towards production. With proper encouragement from the top, English workers would give right results.

THE PROPER USE AND APPLICATION OF TOOL STEELS.

Paper presented to the Institution, Coventry Section, 2nd October, 1929, by J. A. Hopkinson.

THE subject matter of this address is one which commands the absorbing interest of everyone interested in the many branches of engineering to-day, particularly in facilitating production and reducing manufacturing costs, whereby British industry in particular, and all engaged in this important work, can co-operate in the most comprehensive sense to uphold and maintain our national tradition and reputation, of which we have every reason to feel proud.

Members of the Institution will realise that the time at our disposal makes it exceedingly difficult to deal with the subject matter in other than a very brief manner, but I will endeavour to include in a practical way as many of the present-day problems as is possible on an occasion of this description. With regard to the various methods employed in the manufacture of tool steels, I think it would be well to mention these without discussing at length all the details involved.

As you are no doubt aware, the high reputation enjoyed to-day by Sheffield tool steel makers was built up almost entirely by steels manufactured by the crucible process, and despite the claims made by the makers of the various types of electric furnaces, together with the praise imparted by those tool steel manufacturers who have installed these furnaces, there is no definite proof that electric furnace tool steel is in any sense superior when made up into tools than that produced by the crucible method. In making this statement, I may be subject to criticism, for the two methods of melting have their own respective merits, and whilst these could be discussed at length, opinions would remain divided, and after all that might be said, the crux of the matter lies in the actual performance of the steel when made up into tools and the results obtained by their application. In addition to the two processes referred to, quite a lot of the cheaper grades of tool steels are made in the open hearth furnace, but the limitations of tool steel made by this method are so manifest that it would be a waste of time to refer to same at length.

Before discussing the types of tool steel now in popular use, I should like to draw your attention to several very important factors concerned in the manufacture of tool steel, which whilst they are receiving constant thought and attention by the maker of the steel, are often concealed from the user of the steel other than of in the form of faulty tools, and the reason of these failures very often remains obscure. On the one hand, the steel maker suggests faulty heat treatment and general application of the tools when put into commission, whilst the tool maker disagrees on both points and maintains that the steel has been dealt with in the most careful manner and exactly similar in every way to other tools which have performed satisfactorily in commission. The inevitable inquest is held, and it usually results in some form of compromise which is never satisfactory to either party.

It will no doubt be interesting to you to detail some of the incidents relating to manufacture which are responsible for tool steel failures. In the first place, the analysis of the steel is very seldom the cause of failure, due to a general efficiency which exists in controlling same at most of the successful steel making plants of to-day. Ingot defects are usually of such a character that they are detected during the process of manufacturing into bars and consequently scrapped at the maker's works. The troubles, however, which develop during the various stages of manufacture from the ingot to the finished bar are often of an insidious character and difficult to detect during the superficial examinations which take place at each stage of manufacture. The steels most susceptible to the troubles referred to are those of complex character, such as high speed steel. It might be suggested that the basis of controlling each operation should be such as to make it impossible for mistakes to arise, but so long as the human element continues to remain an important factor, mistakes will ever be with us. I will, however, endeavour to briefly illustrate the manufacturing troubles referred to, and take a high speed steel ingot as an example.

In the first place, the size of the ingot has an important bearing on the size of finished bar required. The structure as cast is weak and somewhat open in character, compared with the density apparent in the finished bar. It is therefore necessary to break up and refine this structure by uniformly heating to the desired forging temperature and forging under a hammer of the necessary weight and size, in order to produce a uniform displacement of the mass throughout the bar. If the hammer blow is too heavy, the centre of the ingot is crushed, and lines of weakness are created between the grain boundaries and in some cases definite rupture takes place in the form of a burst centre. Some of you may have seen this defect in bars of high speed steel in the region of five or six inches in diameter, not continuous throughout the bar, but

appearing intermittently as blanks are sawn from time to time, and is often mistaken for a pipe defect. On the other hand, if the hammer blow is too light, the centre of the ingot and for some distance surrounding same will, under microscopic examination, show a structure of an insufficiently close character whilst the material near the surface will be close and refined. If milling cutters are made from such a bar they will be doomed to disaster, for if they do not fracture in hardening, they will invariably break during early application. To the naked eye the fracture appears quite sound, and then ensues the inquest and a verdict which is seldom unanimous.

The control of temperature, both at the forge and mill, is very important in the production of the smaller sizes of high speed steel, for the steel loses its temperature very quickly, and in consequence a condition known to the manufacturer as "cold working" will develop, and no amount of annealing will rectify the trouble. The structure is crushed and in a permanent state of tension and weakness, yet the fracture of a hardened tool will appear almost perfect to the eye. The tool maker will commence to have trouble after the tools are hardened. The steel is then in a very sensitive condition, and although the tools may be subsequently tempered to 600° C., he will find hair lines develop on grinding which may develop into definite cracks over-night, and in the case, say, of inserted tooth milling cutter blades, ground on the flat, the surface will sometimes lift and shell off. Now, I do not wish you to assume that the well known path of hair lines produced in the grinding operation are invariably the result of defective material. As you are all aware, the best high speed steel in a hardened condition is very often ruined by injudicious grinding, but I consider it advisable to warn you that it is highly desirable to obtain tool steel from a reputable manufacturer, who is capable of supplying a uniform product and who will render assistance and co-operation in the application of same.

In considering the question of the various types of tool steel suitable for specific purposes, precedence must be given to what may be termed the high speed steel range or variety used for the cutting or machining of metals. During the thirty years which have elapsed since the first public demonstrations were made at the Paris Exhibition, a remarkable evolution has taken place in the development of high speed steel, due to alloy combinations which during the process of research have been found to possess that quality known as red hardness to a greater and still greater degree, until at last we have reached a position where tungsten carbide can be successfully prepared and applied to produce cutting speeds which might be termed to-day as phenomenal.

Leaving out the old type of self-hardening steel, the first com-

mercial high speed produced contained from 12 per cent. to 14 per cent. tungsten, three to four per cent of chromium, and when compared to plain carbon steel commonly used at that time for cutting tools, the difference was so pronounced as to immediately plunge machine shop production into antiquity. The machine tool builder was then called in to contribute his quota in the way of suitable machines, designed to cut at speeds and feeds up to the capacity of the steel. Since that period, development has continued, both with regard to tool steel and machine tool design.

The introduction of vanadium, in combination with a higher percentage of tungsten, constituted the next real stage of development in the manufacture of high speed steel, and this material proved itself to be so much superior to the plain tungsten chromium type, that it has continued to remain the most efficient and popular grade of high speed steel in general machine shop practice throughout the world. Experiments have been made with other alloys, such as uranium, zirconium, titanium and cobalt, but with the exception of cobalt none of these alloys were found to possess any real commercial advantage as high speed steel constituents. Molybdenum has been used in varying percentages. It functions in a similar way to tungsten, and one per cent. of molybdenum is considered to be equal to two to three per cent. of tungsten, but exhaustive experiments have proved that it is far less reliable than tungsten, being erratic and inconsistent in behaviour, and in consequence is seldom used to-day as a constituent alloy of high speed steel.

The past eighteen months have witnessed the introduction of cutting tools made from tungsten carbide with varying percentages of cobalt. It is not a cast material but is made by forming the finely divided and carefully mixed components. Tungsten carbide and cobalt to the desired shape under hydraulic pressure and then sintering in an inert or hydrogen atmosphere at a very high temperature. The same extravagant claims are being made with respect to this material that were made when "Stellite" was first introduced to the effect that its application will revolutionise machine shop production, and practically eliminate high speed steel in the form of cutting tools. I think it advisable to preserve an open mind with regard to this prophecy. There is no doubt that in the case of selected operations and under ideal conditions, phenomenal cutting speeds can be maintained which leave ordinary high speed steel well in the rear, but there are other factors involved, with regard to cost, difficulty of manipulation, brittleness, machine tool design, which will militate against its extensive application. In addition, there is another factor involved which has not yet received the consideration which will eventually be found necessary. I refer to the machining of components which after they are assembled in complete units, are subject to mechanical strain and fatigue.

Research with regard to machining strains created by the removal of metal at increasing speeds and feeds has definitely proved that beyond a certain limit a stressed condition is produced in the boundary lines of the crystals, even to the extent of rupture and a microscopic examination reveals a condition which is destined to meet with disaster at a later date in the form of a fracture. Even in the case of a component which may not be subject to severe mechanical strain, a surface condition can develop which will play havoc with a white metal bearing. However, with regard to high speed steels generally, there yet remains considerable room for further research, both with regard to control in manufacture and hardening conditions. It is gratifying to notice that manufacturers engaged in engineering production are beginning to realise the importance of up-to-date tool hardening equipment. The old rule of thumb methods are disappearing and equipment to facilitate temperature control is fast being installed. The two factors involved in the successful hardening of high speed steel are time and temperature, or in other words, the amount of heat and the way the heat has been applied; 1,300° to 1,340° Centigrade is the desirable range of hardening temperature, depending upon the form of tool and the analysis of the steel, in order to obtain the best results. High speed steel containing cobalt from five to ten per cent. requires the higher temperature, for this alloy is somewhat sluggish in action and in order to get the carbides of the alloys into proper solution—which in the ideal hardened condition—the higher temperature is necessary.

I think it is now generally accepted, and quite rightly so, that the tempering of hardened high speed steel tools is necessary and advisable. A temperature of 600° Centigrade is effective in nearly all standard high speed steels, and an average period of twenty minutes, depending upon the size of the tool, gives the results desired. If the initial hardening has been performed satisfactorily, the hardness reading is still maintained after tempering. Furthermore, the tool will withstand more abuse in application in the tempered condition and is not so susceptible to the production of hair lines through forced grinding, and in addition, a keen cutting edge on any tool is not so liable to crumble when in commission. You have probably met cases within the scope of your experience where a high speed steel tool is quite file-hard and will give a high hardness reading, yet when applied the cutting edge appears to rub away quickly. This is invariably due to a brittle structure caused by prolonged heating during the hardening operation, and the breakdown of the tool commences with a slight crumbling of the cutting edge, followed by the complete rubbing away of the cutting edge. Had the temper been drawn to 600° Centigrade after hardening, no doubt the performance of the tool would have been satisfactory.

It is on the difficult cutting operations where the maximum of production is looked for that some of the special high speed steels are resorted to. The cobalt high speed steels give excellent performance on cast iron and steel castings where hard spots, scale and sand are apt to be encountered. It also stands up well on heat-treated alloy steels. Cobalt appears to aid in maintaining the cutting edge at or near a red heat and improves wearing qualities. The carbon content of high speed steel is very important and has an important effect on the cutting qualities. A high speed steel containing .80 per cent. will give excellent results on production cutting when not subject to shock, whilst one containing .60 per cent. to .65 per cent. will prove to possess greater toughness at the sacrifice of a certain amount of hardness and cutting ability. High speed steel is also used successfully on certain punch and die operations, but on account of the high temperature required for hardening and the consequent dimensional alterations after quenching, its use is confirmed to a small class of work.

What may be termed a failure in high speed steel is its inability to maintain that keenness of cutting edge which is necessary in order to produce a high quality finish, particularly when machining non-ferrous metals. The reason of this is due to its comparative low carbon content compared to that of a plain carbon steel suitable for a finishing tool. In view of this, it was deemed desirable to introduce something of a special character in order to obtain the quality of finish such as that produced with a plain carbon steel, but with an increased capacity for greater cutting speed. Consequently, an alloy steel commonly known as diamond quality was produced containing approximately carbon 1.30 to 1.40 per cent., tungsten five per cent., with a small percentage of chromium and vanadium. This steel, when hardened in water in the region of 800° to 810° Centigrade, gives excellent results, but its use is not very extensive, due to the more general application of grinding machines in machine shop production for the purpose of decreasing costs, together with obtaining a highly polished surface and accuracy of size.

At the commencement of the present century the range of tool steels in general use was limited to air-hardening steel of the old mushet type, diamond quality just referred to, and plain carbon tool steel. However, with the advent of the electric furnace it was found possible to reduce a number of alloy ores into a ferro condition suitable for re-melting in the crucible, and at an attractive price resulting in extensive research and experiment, with the result that at the present time we have a range of alloy tool steels which can be successfully applied to meet almost any condition associated with engineering production.

The trend of development in the tool steel industry to-day is

of such a character that I am of the opinion that the standardisation of definite analyses to suit specific conditions, together with standard heat treatments, will be correlated and applied almost universally. This will considerably simplify the somewhat complex situation existing to-day, and will make for increased efficiency all round. In the process of this development it is absolutely essential for a close co-operation between the manufacturer and the user of the steel for the simple reason that the steel maker has not the facilities for testing and duplicating the machine shop conditions existing throughout the various industries in which tool steel is used. In the past the mistake made by the steel manufacturer has been a desire to withhold information regarding analysis and certain other information connected with manufacture which would have been very helpful to the user of the material. On the other hand, the steel maker has found it extremely difficult, particularly amongst the larger users, to obtain access to the individual controlling tool design and production, due to the inability of the buying department to see that the contact referred to is imperative if a maximum production efficiency is to be obtained. There is no reason why these difficulties should exist and they are fortunately disappearing at many of the large works who realise what is necessary for a production department to function efficiently.

The subject of die steels is of great interest at the present time for press tool efficiency is a matter of paramount importance in engineering production to-day. Plain carbon tool steel of varying carbon contents was, up to a few years ago, the standard material for punch and die work. Were it possible to compute in value the amount of loss, consequently upon broken dies during the last twenty or thirty years, the figure would be enormous. Complicated shapes in designs made it impossible to eliminate uneven expansion and contraction during the hardening process, and even though the heat treatment was intelligently performed, an epidemic of breakages persisted resulting not only in loss of material, but to a far greater extent with regard to labour costs in die manufacturing and interference with production. To overcome this nightmare, the steel manufacturer realised that the rate of cooling necessary to harden a water-hardening steel was the real cause of the trouble, and was also responsible for the alteration in form which was also an additional worry in precision blanking dies. The solution of the trouble was an oil-hardening non-shrinkable die steel.

The two constituents in addition to carbon which impart oil hardening properties to steel are chiefly manganese and chromium. The first non-shrinkable oil-hardening die steel to become popular was one containing approximately .90 per cent. carbon and 1.5 to 1.75 per cent. manganese, with a hardening temperature of 760° to 770° Centigrade. This quality of steel is still used in con-

siderable quantities to-day and is excellent from a non-shrinking point of view, but its manifest drawback is that the margin of safety in hardening temperature is very limited and slight overheating causes rapid grain growth. This results in a weak structure and brittleness, and in the case of a die the cutting edge would crumble and possess a poor resistance to abrasion and shock.

Another oil-hardening die steel which has been introduced to widen the hardening range and produce a more refined structure is one containing approximately 1.20 to 1.30 per cent. carbon, .75 per cent. manganese, two to three per cent. tungsten, .50 to .75 per cent. chromium, and with a small amount of vanadium. The hardening temperature for this class of steel is 830° to 840° Centigrade. This steel has a high resistance to abrasion and will carry a keen cutting edge. One of the more recent types of oil hardening non-shrinkable steels, and one which has met with a large amount of success, is the high-carbon high-chromium type, containing 2 to 2.5 per cent. carbon and 10 to 12 per cent. chromium. Carrying a high alloy content, its structure is very dense and is very difficult to forge. It absorbs heat slowly and should be held for a considerable time at the hardening temperature before quenching. Where time and facilities permit, pack hardening is the best practice in order that slow heating is insured, and the surface is protected during the lengthy period of heating. When quenched at from 950° to 975° Centigrade in oil, it will develop a high degree of hardness. For many classes of work this steel will harden sufficiently in air, and for this reason it is a very safe steel to use, the risks in breakage being practically nil. This steel is distinguished by a remarkable resistance to abrasion and wear, and in consequence it is unsurpassed where high production is of first importance. The only difficulty with this particular grade of steel is that it is somewhat difficult to machine, but this is off-set by the high production results obtained.

When we come to the hot die steel range, different conditions obtain. The principal requirements are a retention of hardness at forging temperatures so as to resist wear—particularly seeing that parts of the dies in contact with the hot metal even attain a dull red heat at times—also an ability to resist the shock of the forging operation. Further to this, it must resist the constant rapid changes in temperature which, with fatigue, result in small cracks on all sharp edges of the dies. The best steel to meet the conditions enumerated is a steel containing .3 per cent. carbon, eight to nine per cent. tungsten, three per cent. chromium, .25 per cent. vanadium, with the addition of two per cent. of nickel. Some remarkable results have been obtained with this steel. I recently had sent to me two components made in a hard phosphor bronze, one was the first produced and the other was the twenty thousandth produced

from the same die and the loss of form was scarcely perceptible. Unfortunately, the concerns in this country making drop forgings or stampings in steel, claim that they are compelled to use a cheaper die steel than the one under consideration. I quite realise and appreciate their point of view, considering all the factors involved regarding competitive prices, etc., but when it comes to the hot forging of non-ferrous material where accuracy of size and weight is concerned, the proposition devolves itself into one of quality production, and cheap die steels of open hearth manufacture are utterly useless.

Despite the increasing use and application of alloy tool steels, plain carbon steel still continues to be used in large quantities and is more general in its uses than any other type. In fact, there are few operations upon which carbon tool steel cannot be used if properly handled, and if the correct carbon content is applied. The range of carbon contents varies from .65 to 1.50 per cent. and requires a drastic water quench in order to develop the desired degree of hardness. The higher the carbon content, the greater the danger caused by over-heating and the margin of safety is very small. Except in the case of small sections, carbon tool steel after properly quenching shows a hard structure to an average depth of one-eighth inch, with a soft core. For this reason it is highly suitable for many purposes where shock is a factor, but the difference mentioned with regard to structure makes it apparent that the steel is in a state of stress after hardening, and in almost every case tempering is essential.

It is very important, and I cannot emphasise this point too strongly, that whenever possible the tempering operation should be performed immediately subsequent to the hardening operation, for the sooner the hardening strains are relieved, the less likelihood exists for breakage due to the stressed conditions. This particularly applies in large sections and many of the disasters which occur in the form of breakages before the tool is applied, even though the fracture indicates a perfect hardening temperature, are due to delayed tempering. Carbon tool steel loses its hardness on tempering to a greater extent than alloy tool steel. The change up to say 210° Centigrade is very slight, but above this is comparatively rapid. It is this property that excludes its use for applications where hardness is required at more elevated temperatures. I consider that the skill required in the successful hardening of plain carbon tool steels is far greater than applies to any other type.

Had time permitted, I should have enjoyed taking you further into an intensive discourse on so many of the problems arising out of this most interesting subject, but I think it desirable in the interests of all concerned to pause at this juncture and invite discussion on any of the subjects which have been briefly dealt

with, or any other item of interest which may have a relation or bearing on the subject matter before us.

Discussion.

THE PRESIDENT, MR. A. H. LLOYD, remarked that tungsten carbide was a metal which was intriguing them all very much. Many of the members had had first hand experience and whilst they knew its many defects, its virtues were very pronounced. They could not afford to ignore the matter, and he thought it was up to Sheffield manufacturers to give them something better than the present tungsten carbide which presented a wonderful field for research. He also suggested that his experience was to the effect that uranium in combination with cobalt was an advantage as a constituent of high speed steel. He would also like the opinion of the lecturer as to the safe limit in size of high speed steel bars used for milling cutters.

THE LECTURER replied that Sheffield tool steel manufacturers were fully alive to the tungsten carbide situation, and whilst they could be accused of moving slowly in the matter, he could assure them that developments were taking place which would in turn place the industry in the enviable position of supplying the best tool steel it was possible to procure. With regard to the question of uranium, his experience with various combinations did not indicate that this alloy contributed any useful advantage in high speed steel. However, research was not finished in this respect, and it was possible that uranium may be found more useful in the future. With respect to large round bars of high speed steel for milling cutters, a safe limit was $4\frac{1}{8}$-inch or $4\frac{1}{4}$-inch made from not less than a 12-inch square ingot. Larger sizes were, of course, used, but above the size mentioned the forged blank was the better proposition.

A MEMBER asked whether there was any difference in quality between electric furnace steel, particularly that made in the high frequency furnace, and crucible steel.

THE LECTURER said that as yet there was only one make of high frequency electric furnace which had been used for any length of time in the manufacture of tool steel and, in consequence, he hesitated to say what was in his mind because it might be unfair to the makers of that furnace, seeing they were not present, and the matter was perhaps outside the scope of the discussion that evening. When they came to discuss the question from a metallurgical and engineering standpoint, there were advantages both for and against, but the only real test was the performance of steel when made up into tools. In order to make good steel it was necessary to use good raw material, and whether the melting medium

was electricity, gas or coke, it did not matter providing the steel was properly melted and cast into sound ingots. Everything depended upon control, and his experience was that no better tool steel could be produced than that by the crucible process.

Replying to another question, the lecturer said that high speed steel was the most desirable material to use for broaches, from a production point of view, and more and more high speed steel broaches were now being used. Broach making was a specialised operation and necessitated a vertical hardening furnace, together with the necessary facilities for straightening purposes. Broaches made from a high carbon tungsten steel of the diamond quality also gave good results and did not present the same difficulties in manufacture due to a lower hardening temperature and less risk of distortion.

In answer to a question with regard to the best tool steel to use for machining aluminium to overcome some of the existing difficulties, the lecturer stated that for high production high speed steel was the most satisfactory. His experience had been that the difficulties in machining aluminium were due almost in every instance to tool design and unsuitable cutting angles.

A MEMBER instanced trouble his firm had experienced with a composition of an insulating character known to the electrical trade as elephant hide, the machining of which caused trouble due to the rapid generation of heat and the consequent rubbing away of the cutting edge. The lecturer suggested that tungsten carbide or a diamond steel might overcome the difficulty, but after ascertaining the design of tool involved which precluded the adaptation of the materials referred to, he suggested high speed steel as being the most suitable to cope with the heat generated and retain a cutting edge.

Dealing with a point which concerned the use of high speed steel where carbon steel might be used just as effectively and at less expense, the lecturer stated that this position might arise due to the limited capacity of the machine tool, but it was seldom that this position obtained with modern machine tools.

A question was also asked as to whether it was possible to determine the capability of a tool prior to same being applied in the machine.

The lecturer replied that he only wished it were possible to arrive at the merit of a high speed steel tool other than by the actual cutting performance of either durability or breakdown test. The only guide or test that could be applied other than a machining test was proper control in hardening together with 600° Centigrade temperature operation, followed by a Rockwell or Brinell hardness

test which would in some degree determine whether the heat treatment had been satisfactory.

A further question put to the lecturer was, Did he admit of variations in steel of a given grade and, if so, what caused that variation and how were modern steel makers developing methods to overcome the trouble ?

The lecturer replied that research was going on all the time, and up to date manufacturers were constantly improving their methods to eliminate defects arising out of temperature control in manufacturing and other causes due to the human element, and he suggested that a great many of the troubles of the user were not so much due to lack of uniformity in material as to a general lack of up-to-date heat-treatment facilities at the works where high speed steel was being used.

A vote of thanks to Mr. Hopkinson concluded the proceedings.

ELECTRICAL DRIVING OF MACHINE TOOLS.

By David Nicholson (Member).

(*Paper awarded the Prize presented by Sir Alfred Herbert, K.B.E., in the Prize Competition of* 1929.)

Introduction.

IN a general survey of the commercial application of electrical drive to machine tools, it becomes necessary to reach a certain basis of comparison before consideration of details which may not be applicable to every branch of machine tool driving. There is, for instance, a large difference in the problems connected with a plant laid out on mass production lines to a definite programme of output and those connected with a plant dealing with "specials" or moderate quantities of "batch" machines giving comparatively short runs or even single items.

Apart from differences in production programmes, the cost of energy (whether purchased or generated), the nature of the supply, and even the attitude of the executive staff may have a definite effect upon the commercial (as apart from the theoretical) application of electrical drive. Add to these diverse factors such considerations as the type of building, indescriminate dimensions of motors and switchgear due to different makers, and that elusive factor of safety (which can be so elastic on occasion), and the problem assumes huge dimensions.

From this point of view, the standardisation of any one method appears difficult, and in actual practice it is rarely found that the universal application produces the anticipated results, but rather a considerable number of weak spots of a varied aspect. For these reasons also, it is possible to justify the adoption of several entirely different applications in one plant or even in one bay, and it seems probable that in the correct estimation of local conditions lies the solution to the problem of the best type of drive.

It becomes evident that if it is necessary to provide for the economic, commercial, local, and electrical factors in machine tool drives, and have some consideration of the individual purchaser, it is essential that machine tools should be designed in the first place with a view to the adoption of any orthodox drive demanded by the purchaser within limits imposed by economical production.

The conservative attitude of the British machine tool manufacturer has to some extent been justified by these conditions, but the advance in the science of electrical drives is far behind that which

would have been possible had the necessity for close co-operation between the electrical engineer and the machine tool designer been appreciated earlier. It is not the electrical manufacturer that is referred to in this sense, but the inclusion of an electrical engineer on the staff of the machine tool manufacturer applying electrical knowledge to his particular products and with the whole electrical industry to draw upon for apparatus specially suitable for the machines considered. Under present conditions it is even more necessary that machine tools should be considered from more than one point of view, first the product including jig and fixture problems, then the machine, and finally the co-ordination of machine and handling problems with the electrical drive.

When all these things have been accomplished, it still remains in the hands of the purchaser and user to decide if the facts justify the indiscriminate motorizing of machines, which has become the fetish of more than one country.

Section 1.—Methods of Electrical Drive.

It is possible to distinguish three distinct groups of electrical drives which represent general and advanced practice in machine tool drives. Each group is capable of interpretation to individual factors, but may generally be stated as follows :— .

(a) Sectional lineshaft drives.
(b) Individual motor drive through clutch.
(c) The electrically controlled machine.

To distinguish the two latter groups, it is perhaps better to designate group (b) as the Motorized Machine, i.e., a standard machine to which a motor has been added, and group (c) as the Electrified Machine, i.e., in which the machine, drive, and control have been considered as a whole, the effect of which is evidenced in improved production.

(a) The Sectional Lineshaft Drive.

The ideal conception of a sectional lineshaft drive appears to be a high speed lineshaft carried in ball or roller bearings driving a group of machines of the single pulley all geared head type, the power being supplied by a constant speed motor. The lineshaft speeds and belt speeds are arranged to give an adequate drive without the use of excessive belt tension and the use of countershafts entirely avoided. The motor output is based upon the intermittency factor for the number and type of machines, utilising the B.E.S.A. continuous and overload capacity in order to reduce the size of the motor to the economic point. A simple manual (or automatic) starter is used for the motor and a number of emergency stop buttons can be provided if operation conditions render these desirable.

The main advantages may be assessed as follows. High load factor with high efficiency for the motor. The power to each machine

only limited by the transmission. Robust prime mover with simple maintenance and allowing rapid and easy replacement in case of repair or failure. The use of standard machine tools of the single pulley type is permitted, which are obtainable on short delivery and have good resale value. It is usually possible to arrange groups of standard Horse Power which enables the number of standby machines and spares to be kept to a low figure.

The disadvantages depend upon the nature of the layout and generally may be stated as follows:—the use of belting or similar methods of transmission and the necessity of lineshaft supports which may cause obstruction to light, cranes, and conveyors. It is necessary to have correct alignment with the shaft. It is often difficult to arrange economic groups which will allow overtime or nightshift work on a few machines without the necessity for running a motor on light load. Lineshafts of indifferent layout may cause dust accumulations, be unsightly, cause draughts, and present an element of danger if guarding is not efficient.

(b) The Motorized Machine.

The motorized machine in this class is defined as a standard single pulley type of machine with clutch driven by constant speed motor. The motor is normally started by a simple manual starter, and runs continuously throughout the shift. The transmission from the motor to machine may be by belt, belt and jockey pulley, rope, chain, spur wheel, and in some cases a direct coupled drive, and certain limited variations in mounting the motor are possible.

The advantages are stated as follows:—the machine becomes an independent unit and is mobile to the extent that cables can conveniently run to the machine. It enables elastic layout of the plant to be made with rapid re-construction of production layouts when required. A saving in floor space is possible with certain methods of mounting the motor and light and headroom are not obstructed.

The disadvantages are not always so obvious, but are far-reaching in effect upon the whole plant. In any machine tool the power demands are very intermittent and in this type of drive the motor necessarily runs empty or light for a considerable portion of its time. In such conditions the motor efficiency and load factor is very low, and in A.C. motors poor power factor is also present. The output of the machine in the other direction is limited by the maximum overload capacity of the motor and protection is desirable above this limit. The forms of protection with manual starters necessitate the operation of the manual starter each time the motor has tripped and time may be wasted, especially if the size of the motor has been based upon the economic limit. A multiplicity of motors with differing speeds, frame sizes, and control gear is necessary and this may militate against rapid repair or replacement,

whilst maintenance is inevitably increased. If floor space is saved by the use of a built-in or flange type motor, repair or failure may mean that the machine is derelict for such periods, and as the machine grows older the output is more than ever limited by the condition of the motor. The type of transmission may be faulty owing to close centres, and often requires more guarding than a standard machine. It requires an extensive and flexible electrical distribution system with adequate protection against individual machine faults if extensive stoppages are to be prevented. The proportion of installed H.P. to maximum demand produces low load factor, low efficiency, and in A.C. systems low power factor and high maximum demand.

(c) The Electrified Machine.

The electrified machine is defined as one in which the machine, drive, and control have been considered as a whole, as distinct from the motorized machine in which the electrical equipment has a more or less separate entity of its own. The power transmission to the machine may follow any one of the methods used in motorized machines, but the control of the motor is the main machine control giving some improvement in operation or production and possibly combining several auxiliary motors or apparatus reducing the manual effort and designed to give correct and foolproof sequence to all movements. Naturally, the degree of electrification can be very elastic, and it is difficult to tabulate any definite statement of advantages and disadvantages.

In a general consideration of the advantages, this type of drive possesses all the advantages of the motorized machine, but with the much improved arrangement in which the motor has few empty running periods and a much higher efficiency and power factor. The control may be effortless in the sense of wasted movement and can be centralised in compact master control positions. The control can provide for rapid stopping, change of speed, locking and clutch devices, limiting devices, and special feeding and indexing movements, all if need be under control of one lever. Practical and efficient safety devices can be incorporated which effectively protect the motor and machine from misuse, and which automatically reset when the cause or overload has been removed. The electrification of a machine provides for a reduced number of parts for mechanical transmission and often simplifies the design of complicated machines.

The disadvantages include increased skilled maintenance, possible lengthy periods for repair of special parts, and the possibility of enforced stoppage due to failure of an essential auxiliary. The adjustment of such machines is often beyond the type of maintenance staff found in small works, and local electrical regulations may militate against simple control gear being used. Unification

of mechanical and electrical controls may be badly applied, due to lack of vision on the part of designer or purchaser, and there is a distinct difficulty in standardising any one method of control and arrangement which will meet the many specifications which may be put forward for such machines. The delivery time for such machines must necessarily be longer than for standard machines and the number of special parts larger. A disadvantage which may be serious in small plants is the frequent starting peak current, but in larger plants this disadvantage is not so serious.

A.C. versus D.C.

Coming to the question of alternative types of supply for all the above classes of drive, there are a few essential differences to be considered. In the direct current motor, the question of speed, speed control, dynamic braking, inching, reversal, starting torque, and efficiency are simple problems, but present some difficulty in alternating current control. The chief advantages of the alternating current motor are in its simple and robust construction, but in any attempt to obtain the main attributes of D.C. machines, it becomes as costly and loses its simple features. The trend of electrical supply is definitely toward alternating current, and it is possible that some of the disadvantages of A.C. control may disappear at an early date, so that the preponderating advantages in supply are due to the simplified distribution over large areas possible with A.C. supply.

Comparing A.C. motors and control with D.C. apparatus in the matter of convenience, D.C. control is usually easier and is capable of meeting conditions which may prove impossible to A.C. apparatus. Variable speed A.C. motors have not the simplicity or good characteristics of the D.C. variable speed motor, and in any drive requiring high starting torque the A.C. motor is at a disadvantage. The simple dynamic braking possible with D.C. motors, require the use of electro-mechanical or reverse current braking in A.C., and convenient slowing down or crawling speeds are difficult and inefficient. The question of power factor is very important in machine tool shops, and a more considered comparison from this point of view is made under the heading of cost and in Section 5 when considering the effect upon works layout, etc.

Section 2.—Comparison of Costs.

When examining the relative costs of electrical drives it is necessary to distinguish between not only the type of supply and the nature of the drive, but also to estimate a relationship to the productive capacity of machines driven by alternative methods. The high capital cost of one machine may be adequately offset by increased production and when new layouts are considered it is necessary to go into the whole subject very carefully if the best system is to be chosen. The estimates in this section are based

upon present day costs and methods and are intended to cover general applications, since it is impossible without set conditions to enter into close estimates.

(a) Initial Costs of Electrical Drives.

In the three general classes of drive discussed in Section 1, the sectional lineshaft drive is a useful basis of comparison, and taking as a standard of safety an installation based upon the Home Office, Board of Trade, and regulations issued by the Institution of Electrical Engineers, we can base the cost of an A.C. lineshaft drive at 100 per cent. and the D.C. lineshaft drive as 140 per cent. The relative costs are based upon 20 to 30 H.P. units, including motor, switchgear, lineshaft, pulleys, ball bearing hangers, and installed in buildings of the steel frame type. Coming to the motorized machine, a close examination reveals that the type of application does not affect the cost very largely and that the addition of motor, switchgear, floorplate, etc., comes within a small variation whatever the type of transmission adopted. At first sight it may be thought that a single belt with jockey pulley drive would be cheaper than a chain or spur wheel drive, but it is found that the cost varies very little. The relative costs to the lineshaft drive are 150 per cent. in the A.C. drive and 190 per cent. in the D.C. drive. Due to the degree of elasticity in the arrangement of electrified machines, it is difficult to estimate to any reliable degree how far the unit cost may be compared. It is safe to assume that the elimination of clutch, operating rod, and a reduction in transmission shafts will to a large extent offset the increased cost of switchgear, and it must also be remembered that the difference in cost in manual and automatic gear becomes less as the output increases. The cost of automatic starters is also on the down grade owing to increased demand, and likely to be accelerated in this direction. The general estimate of cost on the previous relationship is placed at 170 per cent. in the A.C. drive, and 200 per cent. in the D.C. drive. These costs may be reduced in large and complicated machines since any increase in electrical controls produces an equivalent elimination of mechanical parts.

If the comparison is to be fair, it is necessary to include as a first cost the provision of power factor correction gear which is necessary in A.C. machine tool drives if the current costs are to be equal to the costs in a D.C. supply. The additional capital cost that must be added to each motor drive for separate correction to each motor is 20 per cent. in the lineshaft drive, 40 per cent. in the motorized machine, and 30 per cent. in the electrified machine.

(b) Running Costs.

Running costs in this case are divided into power costs, including all charges, and maintenance costs. It will be obvious as far as

running costs are concerned that the method of transmission from motor to machine has but little bearing upon the power costs, provided good design is present. Whether the transmission consists of belt, belt and jockey pulley, rope, chain or spur wheel, the average efficiency of all these drives falls between limits which preclude any serious economies being made. The application of any one method may make a considerable difference to the starting torque and to a less extent in the running torque, if ball or roller bearings are used throughout. As far as maintenance is concerned, the factor of safety allowed in design has a considerable influence, but all things being equal it is considered that the direct drive to gear box, or with one reduction by spur wheel outside the gear box, takes the first place for economic maintenance with silent chain drive taking the second place and rope and belt drive following closely. It should be remarked that the belt and jockey pulley drive is likely to be more expensive in maintenance than the straight belt since the jockey pulley puts a large strain upon the belt and reverses the strain on the fibres at every complete revolution of the belt. The peripheral speed of the jockey pulley is identical with the belt speed so that ball bearings are essential.

Coming to power costs we enter into a more direct comparison of A.C. and D.C. motors. At full load both A.C. and D.C. motors are highly efficient, but both the efficiency and power factor of A.C. motors fall off badly at light load, whilst the efficiency of the D.C. motor at light load is fairly good. Taking an example of a machine tool load on A.C. supply using induction motors and without power factor correction, investigations show that the load factor approximates 30 per cent. on $8\frac{1}{2}$ hour shifts and that the power factor of the combined plant is approximately 0.5 to 0.6 lagging. Assuming that the cost of supply is based upon a fixed charge per kVA of maximum demand plus a fraction of a penny per unit, the cost of the current will be 30 per cent. to 35 per cent. more than that of a D.C. supply at the same tariff. If special motors or plant are installed to give power factor correction up to 0.9 lagging, the cost of the current will then be the same as an equivalent D.C. supply but the cost of the plant will equalise the relative A.C. and D.C. capital costs.

The above example is capable of infinite variation as regards load factor, power factor, tariff or generation costs, maximum demand and capital costs, and it is necessary closely to tabulate the various factors in unit costs if the correct relationship of any one method to another is to be found. Given the tariff or generation costs, the installed horse power, a knowledge of the type of motors, control, and machines, and experience in the intermittency factor due to the type of product—it should be possible to obtain definite relationship of costs due to any one method, and it is to be expected that such methods of comparison will eventually give a lead to

the use of desirable features in machine tool drives.

(c) Summary of Costs.

The following table gives a general summary of costs based upon a machine tool establishment with a total installed H.P. of 1,200, using both D.C. and A.C. supplies and with approximately equal proportions of machine tool drives of the types designated (a), (b), and (c) in Section 1.

TABLE I.

(a) Sectional lineshaft drives.
(b) Motorized machines.
(c) Electrified machines.

Unit Costs.	A.C.			D.C.		
	(a)	(b)	(c)	(a)	(b)	(c)
Capital costs	100%	150%	170%	140%	190%	200%
Capital costs, power factor costs	20%	20%	20%	—	—	—
Maintenance costs ...	100%	110%	115%	105%	115%	120%
Power costs	100%	120%	110%	100%	120%	105%
Relation to production costs	130%	135%	105%	125%	130%	100%
Cost per unit production	1.00	1.18	1.15	1.01	1.23	1.16

In justice to the above table it must be made clear that many of the machines under (c) could not have been belt driven from lineshaft and the general inference to be drawn is that motorized machines do not offer the return to capital expended, and that electrified machines should, except in certain cases be confined to special machines too complicated or unsuitable for belt drives. It is also true that the extra cost of the machine under (c) is offset in many cases by a cheaper mechanical layout of the machine. This should make it quite clear that the electrical drive of a machine tool should be part of the machine, and any increased cost in the electrical equipment be reflected in a saving of mechanical parts. Only by these methods can individual drive be expected to give return for capital equal to the group diven machine.

Section 3.—Comparisons of Efficiency.

Since the cable distribution system of a factory replaces to a large extent the mechanical power transmission of earlier days, the fact emerges that whilst the transmission losses in the older power plant were more or less constant in value, the losses of an electrical system are more in proportion to the load at any one instant. Whilst this is correct for D.C. transmission the efficiency

of A.C. circuits depends to a large extent upon the power factor of the current. Where a transmission shaft could be overloaded without any notable increase in transmission losses, an electrical circuit cannot be overloaded without an increase in losses and a probable drop in voltage similar to the drop in speed of an overloaded shaft. It is therefore essential that cables of ample section should be provided to meet all demands without excessive voltage drop, and provided these conditions are carried out a supply of current is available at the motor terminals in a highly efficient manner. Distribution systems for motorized and electrified machines must be adequate if heavy losses are not to be present and the output of all motors in the circuit kept as low as possible consistent with the duty. Under B.E.S.A. No. 168 of 1926, all continuously rated motors are capable of withstanding 25 per cent overload for two hours and 100 per cent. overload for 15 seconds without injury, and these valuable features must be made use of in machine tool drives if the transmission losses are not to be equal, if not greater, than those due to earlier methods. If the load produces low power factor, it is possible for both motors and cables to be overloaded with only a moderate power in the circuit and a large voltage drop is probable which further increases the power losses in the circuit. Machine tools generally are not machines in which the *average power* is high, and usually have a period of heavy load during the roughing cut followed by a light load during the finishing cut with idle periods during setting up, tool changing, and sharpening, etc. The group drive provides for these undesirable load features in smoothing out the load peaks and light loaded periods and giving good efficiency with high average load for the motor. A great improvement in single machine drives is possible by the use of duplicate works tables, revolving work tables continually feeding work to the machine, in fact, any method of providing continuous cutting with a minimum of light loaded periods can produce large economies.

Further economies in power transmission can be made by the elimination of transmission shafts, gears, etc., and placing the motor close to the work and using control methods as in electrified machines. In the motorized machine such economies are impossible since the transmission losses usually amount to the same value as those due to sectional lineshaft drive, which losses, by the way, are spread over a number of machines.

Since the whole object of individual drive to machine tools is to obtain increased efficiency and productivity, the following provisions must be observed if any measurable amount of saving is to be evident. (a) Eliminate transmission losses as far as possible by placing the power close to the tool point. (b) Utilise continuous feed methods as far as possible. (c) When the product allows, use separate machines for roughing and finishing e.g., rough turning,

finish grinding, and so ensure full load for the motor as much as possible. (d) Reduce wasted production time as far as possible by providing centralised, effortless control. (e) Further reduce loss of production time by the use of jigs, fixtures, and handling methods, especially if any quantities are present. Lacking these essential provisions, it is probable the capital and running costs of individual drive will be out of proportion to the benefit gained and will show no saving over more simple and proved methods of machine tool drive. In fact, the provision of a motorized machine is in some ways comparable to providing an expensive and complicated fixture for the machining of one or two jobs of low value. If the work and the quantities are present, the use of an electrified machine can produce large economies, and savings in production costs up to 50 per cent. over older methods are possible.

Section 4.—Design of Electrically Driven Machine Tools.

Even a brief consideration of the problems facing the machine tool designer in providing individual drive to machine tools, reveals the really difficult nature of any attempted standardisation. The transmission adopted may fail to meet individual requirements of purchasers or their consultants, and it is always difficult to reconcile the adaption to meet the varied specifications for electrical equipment, which may specify both the maker and type of gear to be supplied. A source of continual difficulty is the ever varying dimensions of electric motors, the difficulty of obtaining vertical or flange mounting machines from makers who do not standardise these mountings, and in many cases the necessity for using electrical equipment provided by the purchaser.

From this maze of contradictions emerges several definite facts which are of direct importance in machine tool design. (a) That cone driven machines cannot be included in individual drives. (b) That the variable speed motor must be neglected, using all geared drives providing a range of speeds suited to all classes of work, and where a variable speed motor can be used, a smaller range of gear changes. (c) The machine must be so designed to provide for economic adaption to (1) fast and loose pulley; (2) single pulley and clutch; (3) standardised unit adopted by the machine tool manufacturer; (4) motorized or electrified drive; (5) any *orthodox* method demanded by the customer. (d) An alternative to (a), (b), and (c) is the rigid standardisation of a new line of electrified machines, designed to be the last word in performance, efficiency, and output, fully guaranteed and backed by an efficient service.

Let us examine the practical application of these conditions. In the matter of cone drives, the present policy of manufacturers appears to be to allow them to die a natural death, but it seems

certain that if mass production of unit gear boxes was attained, that the cone drive would become special and if enquired for would prove to be no cheaper than the all geared drive. Thus the rigid standardisation of all geared drives would reduce the number of designs and cheapen production. Except in special drives the use of a variable speed motor is becoming limited, especially since A.C. supply will eventually be predominant in the *average* of manufacturing plants. In cases where an infinitely variable speed range would be of advantage, any range above 2 to 1 ratio means an expensive motor, and 3 to 1 may be regarded as an economic limit. These limited ranges are not large enough for general purpose machines, and even high production machines on special work require a larger speed range. The standard gear box should provide for the omission of a number of changes and be available to supplement the variable speed range of the motor.

The fast and loose pulley and the single pulley and clutch drives must long remain with us, and present little difficulty in standardisation.

In the adoption of a standardised driving unit for individual drive, the designer treads on dangerous ground, and even to-day, manufacturers have almost given up the hope of impressing their ideas of such units upon their customers. It is also difficult to find a unit which will satisfy both the home market and the export market, and if general acceptance by the majority is to be gained, the unit must conform to a high standard. Further than this, the unit must be superior in power transmission, silent running, reduced floor space, be easily guarded and of simple maintenance, suitable for use in all climatic conditions, and allow the use of any frame size, type, speed, or make of electric motor without costly alterations. In Figure 3 a type of standardised unit is suggested which has several qualities which make it worth consideration. The adoption of standard worm drive units in other branches of engineering is not new, and there are a number of reputable firms manufacturing such units at competitive prices. The manufacture of such units is not beyond the plant of most machine tool manufacturers, and the following general advantages are given which encourage the use of such a unit. (a) Permits the use of a high speed motor, thus reducing size and price. (b) Silent totally enclosed drive running in oil. (c) The motor relieved of all driving strains in the bearings and permitting universal application of ball and roller bearings. (d) Can be used for all directions of drive, permits horizontal or vertical structure and often obviates the use of special floor plates. (e) Can be standardised in a number of sizes, with no limit to the power to be transmitted.

If a customer demands an alternative drive to the manufacturer's standard he must of necessity pay for his requirements, but a certain amount of foresight in design can provide for a number of

alternative arrangements which can be adopted at a cost which will not preclude the order being gained. The main body of the machine should carry facings, which, combined with the general outline of the machine and softened by rounded edges would provide seatings for alternative methods of drive without affecting the general appearance of the machine. The cost of alternative drives can be reduced by such provisions.

In the case of choice between the motorized machine and electrified machine, the transition is usually a fairly simple one and consists in eliminating the clutch and operation rod and substituting electrical controls for mechanical controls. The machine control can then be by pushbutton stations, centralised control stations, by spline shaft controller (in which the controller is fixed at one end of the machine and the operating handle moves with the saddle), portable stations, and if required, combined controls for auxiliary movements. The extra cost of switchgear is usually offset by savings in mechanical parts and increased production is obtained.

The machine tool manufacturer who can so far forget orthodox design and produce a line of machine tools in which product, machine, control, and handling methods have been considered as a whole, giving the maximum of convenience and productive efficiency and backing his product by efficient service methods, will lose many orders against prejudice and conservative designs, but will gain an ever-growing stream of batch orders for production layouts. This type of design has already gained ground in the heavier type of machine, and must eventually spread to the smaller machine. The general lines of this policy includes the provision of the maximum power at the tool point up to the loading of new cutting mediums, the reduction of transmission and friction losses, automatic lubrication, high speed heat treated gears with corrected teeth, and effortless centralised control for all movements including handling methods. Continuous feed methods are used as far as possible and the minimum wasted production time ensured.

The following summary of controls indicates the convenience possible in such machines. A.C. supply. The use of high torque squirrel cage motors giving full load starting torque with twice full load current. Pushbutton control of stop, start, inch, reverse current braking and reverse inching, two and three speed control with constant torque. Clutch and locking movements by contactor type magnets. Single speed hoists for handling product. D.C. supply. The use of shunt and compound motors giving high starting torque in proportion to the current. Pushbutton control of stop, start, inch forward and reverse, dynamic braking, slow down, speed up, and infinite speed range with constant torque at low speeds and constant H.P. at shunt speed range. Clutch and locking arrangements by contactor magnet operation and magnetic chucking devices. Variable speed hoists for handling product.

A correct sequence of operations by one control lever can be arranged and foolproof interlocking ensured.

It should be realised that the fine degrees of flexible control can only be considered adequately if a full knowledge of the product is available, and it is certain that the full advantages of electrified machines can only be realised and applied when studied from this view. Such pre-knowledge is possible for certain standard machining problems, but in a large majority of cases this information is not available until the enquiry is placed. To meet such conditions it is necessary to standardise unit heads, saddles, tables, etc., which may be built up to meet the demand for machining special products, and such units must necessarily be self-contained in the matter of power, speeds, and control. The work of unification on such compound machines must be sub-divided and whole-hearted collaboration is necessary in electrical, mechanical, and fixture design if the machine is not to present the patchy appearance so often found in motorized equipments. Careful design can provide for each unit part of the machine to be an independent and mobile unit. with a complete range of self-contained speeds and controls, whilst presenting no difficulty to unified control when desired.

Section 5.—Factory Organisation, etc.

Consideration of the question of supply turns upon tariff or generation cost as the most important factor. If a bulk supply (which will certainly be alternating current) is available at a tariff enabling current to be purchased at a nett cost of 1d. per unit or less (including all fixed charges, etc.), it is doubtful if there are many advantages to private generation. A machine tool load is not conducive to economical generation in a small plant, and unless some method of improving the load factor is available, efficient running is not easy on a large plant. In a purchased bulk supply, some thought should be given to obtaining services from two feeders, and when this is possible continuity of supply is largely assured. Even the complete breakdown of the supply station would not prevent a supply in normal circumstances as the present interlinking of main stations is rapidly proceeding. The small private station would be at a disadvantage in similar circumstances unless duplication of units was made.

The question of power factor is important whether energy is purchased or generated, and it is possible to obtain good power factor and working characteristics and have available a supply of direct current if the following system is carried out. Purchase or generation of A.C. supply at high tension and distributed to substations at economic points. A low tension distribution can be taken from substations and a rotary convertor or motor generator set installed to give D.C. supply. The over excitation of the rotary or synchronous motor generator would provide power factor correc-

tion and ensure low generation, distribution, and supply costs. A typical layout on these lines giving duplicate services with a minimum of voltage drop, economy in copper, and flexible distribution is shown in Figure 4. To a machine tool manufacturer both A.C. and D.C. supply are essential if motor driven equipments are to be tested. In any machine tool shop the convenience of having both supplies has only to be experienced to be appreciated, and often solves difficult problems connected with cranes and other services which are more satisfactory on D.C. for engineering work.

If the organisation of a factory is to be efficient it seems essential that all maintenance services should be under the control of one head. The head of the department may be allied to the technical staff and in active co-operation with the production staff. The subdivision of electrical and mechanical labour can be under charge of senior men and allow of exchange of labour when necessary and desirable. It should not be necessary to draw from production staffs to meet peaks of maintenance and repair and the maintenance staff can always be found with a certain amount of productive work to justify the reserve of staff necessary to meet adequate maintenance. The maintenance of electrified plants is considerable and breakdowns should be prevented by inspection and maintenance programmes carried out systematically and under record. If production programmes are not to be disorganised, the same thought and care given to their planning should be devoted to adequate maintenance.

A complete analysis of working costs under separate headings should be possible from the records of the maintenance department, and where necessary, supplemented by generation costs when private generation is carried out.

Section 6.—Operators' Safety and Comfort.

In the old type of lineshaft drive with its attendant countershafts and belts in all stages of repair, there was always a large element of danger from belting alone, since guarding could not be adequate. In case of accident it took a considerable time to stop the machine, and accidents as a rule were serious. The single pulley type of drive with clutch and brake motion removed many of the dangers, but considerable effort and movement are still required before the machine can be stopped. Belting can cause draughts, which, although inconsiderable for a moment, have distressing cumulative effects when felt for a period of a shift. The same trouble is found with often worse effect due to the ventilation fans of electric motors, and some thought should be devoted to the position of such motors. When pushbutton control is used, it is safe to assume that serious accidents may be lessened since quick stopping can be easily arranged without moving from the tool post. Electrical accidents may be quite numerous if proper protection to cables is not made, and it

should be assured that all cables should be provided with metallic protection over their whole length if entire safety is desired. Machines can become electrified and give dangerous shocks if care is not taken to earth the motor and any auxiliary controls connected to the machine. If an electrically driven machine is in a state of bad repair, it usually produces a nervousness in the operative which lessens production, and there are classes of operative who take a long time, in fact, who never get used to an electrified machine, and who cannot give the increased production possible.

The maximum degree of comfort and effortless control can surely be provided in electrified machines provided the controls are placed in safe positions, and good installation and maintenance assured.

Section 7.—Change Over to Individual Drive.

There are many machine shops with a majority of countershaft driven machines with speed cones and two speed countershafts, which present distinct difficulty in changeover to individual drive. Next to scrapping the machines or providing new unit gear boxes, it seems necessary to modernise the shafting and divide them into groups for sectional lineshaft drive. In isolated cases (for large machines) the use of a two speed motor, driving by any convenient method to countershaft, is an economical solution, but in no way increases the efficiency of the drive. With single pulley drives much depends upon the pulley speed of the machines, and if this is low it is still the most economical proposition to use sectional lineshaft drive. There are a number of motors on the market with self-contained reduction gears which enable a direct drive to machine shaft to be made, and the use of these units with a simple auto-starter make a good arrangement in which some increase in production is possible. The use of jockey pulley drives for conversion purposes has been almost universal on the Continent, but it is to be feared that slow speed British motors (which are generally essential owing to machine speed) make the cost rather high in Great Britain.

In many cases, the conversion of old machines to motor drive seems like putting new wine into old bottles, and unless the equipment used has a strict bearing on resale value, the proposition is far from a good investment. A motorized plant (it is difficult if not impossible to make it an electrified plant) of this character has a poor load factor, a high maximum demand, high power costs, and inevitably contains a large number of indifferent drives which are inefficient and costly in maintenance. The best arrangement that can be hoped for is the adoption of a driving unit similar to that shown in Figure 3, eliminate clutch or belt motion, and use a simple push button starter for control of the machine giving start, stop, and inch with dynamic braking for quick stopping.

This would give an improvement in production, safety in control, eliminate belts, give reduced floor space, and increased light and headroom, and the unit would be available for use with new machines as the old ones were substituted. The capital expenditure for individual motor drives could not be justified in any other way and would be wasted money spent upon a fetish, unless improved production was the result. Increased production is the only means of justifying a capital cost of such a nature, and the mere adding of a motor to a standard machine does not improve the output.

Section 8.—The Best System of Drive.

Individual drive of machine tools presents so many contradictions that it is difficult to apply close reasoning and obtain a simple solution. If we regard the electric motor as a simple driving medium, we obtain no other advantage than that of saving transmission losses and a certain amount of convenience in layout. These advantages alone could not justify the heavy capital expenditure necessary and some further quality must be present to put the matter on a sane basis.

On general purpose machines, little can be saved in production time, and only in the case of high production machines can increased facility for production be of real value. In the general purpose machine, the relation of running time to idle time necessitates the use of a machine which is merely versatile in the number of different jobs it has to handle. The high production machine on the other hand is kept working at high speed on the one job and increased production time is of vital importance. If the application of the power to machine makes an increased cut possible it will be used, in fact, any convenience in control is a valuable asset.

It becomes a simple fact, that individual drive of a machine tool is only really justified when improved production goes with it. *Motorizing* of machines is not suffcient, does not prove a good investment, and merely transfers the duties of the millwright and the beltman to the electrician. *Electrify* your machines and an immediate gain is possible, but there is still the warning—if the increased production possible is not utilised—the investment is still doubtful.

Individual interpretation of machine tool driving will always be to contend with, but the interpretation does not matter so much as the principle behind it—to *electrify*, not merely motorize.